A Review of Environmentally Friendly Materials in Tyre

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Abstract. The article reviews the impact of tyre granules on the environment and how can this issue be mitigated. Tires are made from synthetic rubber, natural rubber, fabric and wires, and it plays a significant role in transportation. Although tire can achieve 100% recyclable and have a complete End-of-life cycle, it is still a threat to the environment. Friction prompts tires to have thermo-oxidative degradation and results in tire damage. Tyre granules fall off, which leads to aquatic contamination that causes by precipitation wash away from roads and flows along with the water stream. Styrene-butadiene rubber (SBR) and carbon black are the significant components of tyre granules, and high heat induces the dispersion of volatile plasticizers and pyrolysis, which pollute the atmosphere. Thus, the goal is to find long-lasting tires, more stains, and more resistance to stress; at the main time, all the materials are environmentally friendly.

Keywords: Tyre Granules; Natural Rubber; Recycled Tire Waste (RW); Graphene Nanoplatelets Nanocomposite (GNP).

1. Introduction

The impact of tires itself is not as problematic as other contaminations, but the use of tires in a vehicle has significantly increased the demand for tires since 2015 [1]. ‘Tyre’ and ‘tire’ both mean a rubber covering for a wheel, and ‘tire particles’, ‘tyre granules', and 'tire wear' are applied to the same thing: wear and tear particles from tyres. Rubber bales mainly produce tyres, textiles, steel cords, and chemicals like 48% styrene-butadiene rubber (SBR), 47% carbon black, silica, etc. [2]. This article will focus more on tyre treads, which are the rubber bales that contact with road particles. According to Baensch-Baltruschat’s finding, 1.3 million tons of tyre wear are produced by roads in Europe annually [3]. Tyre particles will break down microplastic through weathering and result in volatile contents emitted to the atmosphere. Also, it can enter the aquatic system through water away from rainwater and ultimately impact marine species. The overwhelming microplastic will carry by the gyres and accumulate with the garbage patch in the ocean. Other than that, tyre particles smaller than 10 μm will be generated by the tyre wear and tear and become airborne particles, a threat to human health [1]. A tiny particle with abundance can cause a significant impact that deserves attention.

For natural rubber particles in tyres, the half-life is 16 months in soil for it to degrade, and it will take longer and various steps for a truck tyre to do the degradation in the environment, which leads to the human need to manage waste tyres. As most tyres are made from natural rubber, they can be degraded by microbial under aerobic and anaerobic but only if toxic constituents are eliminated from the tyre rubber [4]. The Baensch-Baltruschat emphasizes that a minor amount of pure tire wear particles is found in the environment; most particles are found mixed with road particles, so it induces the cycle of degradation to become much longer than it should be [3]. Thus, to focus on this issue, it is significant to have an equilibrium between tyre use and the environment; technology innovation also is essential to encourage humans to solve the hot potato.

Reducing the abrasion of tyre particles is an efficient starting point; it mitigates the continuous impact on the environment. Strain, strength, and thermal properties are the main factors affecting the lifetime of usage. High strength, ductility, toughness, and better thermal degradation are the most optimum conditions when the tyre's shear and friction force is running on the road; it can against the weather and rugged road condition. Heat and friction also can alternate the chemical composition of generated particles in a tyre. Waste tyre recycling is necessary to be 100% and complete the product

life-cycle, but the environmentally friendly composites can effectively solve this deterioration from the root.

This article will reveal various possibilities and processabilities of the environmentally friendly tyre and focus more on finding less harmful tyre materials are the main target. The article lists the accessible method for researchers or scientists to summarize and conclude the exit resolutions.

2. Characteristic and Materials

2.1 Tyre

Baensch-Baltruschat provides all the ingredients needed for making a tyre tread, and it also highlights that the various proportion in mass components can result in different uses [3]. Like duty vehicle tyres only contain little or no SBR. The components of tyre tread and the other components determine the lifespan and usage characteristics:

Table 1. Materials and chemicals in common components.

Common components	Mass (%)	Materials/Chemicals
Basic material	40-50%	Natural rubber and synthetic rubber, e.g. styrene-butadiene rubber (SBR) or butadiene rubber (BR)
Filler	30-35%	Typically soot/ carbon black (C), silica (SiO_2), and chalk ($CaCO_3$)
Softener	15%	Oil and resin
Vulcanization agents	2-5%	Sulfur (S) and zinc oxide (ZnO)
Additives	5-10%	Preservatives (cyanoalkanes), anti-oxidants (amines, phenols), desiccants (calcilum oxides), plasticizers (aromatic and aliphatic esters), processing aids (mineral oils, peptizers)

According to figure 1 from Jusli's research team uses energy dispersive X-Ray to determine the tyre compound from waste tyre rubber particles [2]. It indicates carbon has contained the most. The research concludes that carbon, silicon, zinc, calcium, and magnesium are the main elements. However, these elements are not all come from pure tire wear particles; it has mixed or attached with road particles.

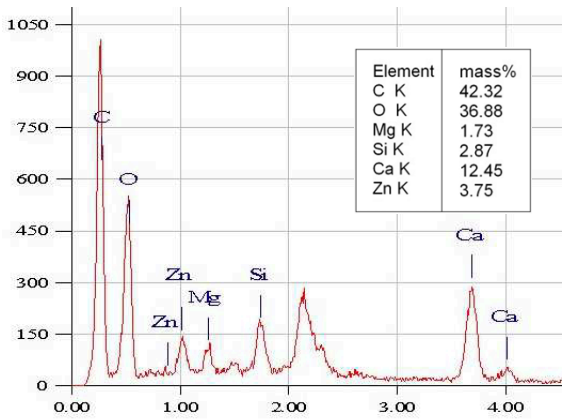


Figure 1. Energy dispersive X-Ray of rubber tyre granules

3. Current Optimal Materials

3.1 PLA

Poly (lactic acid) is biodegradable from crops like sugarcane, potatoes, and corns. It is a linear aliphatic thermoplastic polyester with a great potential to substitute the petroleum-based polymer. PLA is one of the processable and environmentally friendly polyester that brings a bright future to the material. Table 1 provides a list of common components in materials and chemicals to manufacture a tyre. In Bijarimi's research, the article points out that the PLA is a complex process material because of its brittleness [5]. Thus, it has to blend with other polymers like polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polypropylene (PP), and natural rubber (NR). The research team focus on the most efficient scale between recycled tire waste (RW), graphene nanoplatelets nanocomposite (GNP) and polylactic acid (PLA). After all the experiments shown, RW 70/ PLA 30 is the optimum blend. PLA blend with the components from table 2 decreases the brittleness and toughness, which are increased the performance for tyre road conditions. Adding GNP helps to enhance the inferior property of recycled tyre waste compounds as it is chemically inert, preventing interaction with rubber. Figure 2 shows the structure of how it looks when graphene composites with rubber. After adding GNP, RW70/PLA30/GNP2 and RW70/PLA30/GNP3 are the optimal results with 0.63MPa and 0.78MPa of stress, representatively (figure 4). It has high strength, ductility, and toughness, and blending more GNP will increase the tensile strength of tires. At the same time, both results show that it can significantly reduce pore and void in the binary blend.

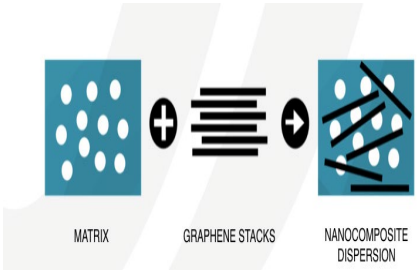


Figure 2. Visualization of graphene mixing up with rubber

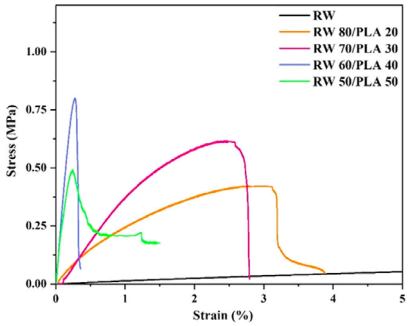


Figure 3. Stress-Strain curves of RW and RW/PLA blends

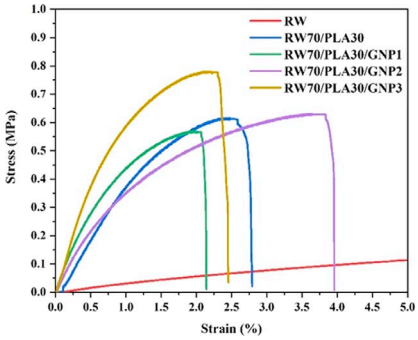


Figure 4. Stress-Strain curves of RW, RW/PLA and RW/PLA/GNP blends

All the components in the table have advantages and disadvantages; using different polymers can result in various changes in tires' brittleness. It takes more research to get complete data on adding each component with PLA. Although in Jusli's research, they are using the waster tyre, it also contains a different percentage of components and scale [2].

Table 2. Function and disadvantage of each polymer that use in tires

Components	Type	Function in tire	Drawback
Polycarbonate (PC)	Thermoplastic polymer	Lower stress from speediness, molding and welding.	Ageing is easily caused by photodegradation, so it requires a coat. It will get brittle over irradiation time (Collin. S, 2012).
acrylonitrile butadiene styrene (ABS)	Thermoplastic polymer	Get rubber toughness and distribute elastomer throughout the rigid matrix.	Release carcinogens and Ultrafine particles (UFPs) can be harmful to humans when manufactured (Unwin, J., 2013).
polypropylene (PP)	Thermoplastic polymer	Commonly known as plastic with high chemical and fatigue resistance.	Photodegradation and thermo-oxidative degradation can cause PP to biodegrade even under an aerobic and anaerobic environment (Canopoli, L., 2020).
polyethylene terephthalate (PET)	Thermoplastic polymer resin	Suitable material for tire breaking strength, thermal stability, and toughness.	Crude oil is the resource of PET. Residence time and/or melt temperature can affect the molecular weight and change the brittleness.
natural rubber (NR)	Natural rubber	Mix with other thermoplastic polymers. Resist to tear and fatigue crack.	Tyre granules can be absorbed by UV and induce greenhouse gases (GHGs). It is an environmental pollutant and can be harmful to species.

4. Conclusion

This article is to help readers to have a better understanding of tyres' function and the possible material that can be replaced in the future. A tyre needs to resist stresses, rigidness, and a thermal environment. At the same time, it also needs to be long lasting, and materials should be sustainable since tyres are commonly used in daily life. Therefore, using environmentally friendly materials mitigate the contamination of tyre. Scientists have proved that polylactic acid and graphene nanoplatelets nanocomposite are safe materials; both materials react stable when they mix. It provides a bright future for getting a perfect environmentally friendly tyre.

5. Current Study

In the current study, using PLA in tires can reduce the harmful material to the environment, as it takes time to degrade and cannot digest from organisms' bodies. Some tire companies have started to use PLA and advertise with this technique. Numerous scientists are trying to find the most substantial tire that can have a longer lifespan. For my study, I want to conclude all the tire components and briefly introduce some possible preparation that more manufacturers can use.

6. Future Suggestion

More new studies will be coming up; the article might not be as efficient as time goes on. However, a brief introduction of tyres with PLA still plays a part.

References

[1] Kole, P. J., Löhr, A. J., Van Belleghem, F. G., & Ragas, A. M. (2017). Wear and tear of tyres: a stealthy source of microplastics in the environment. International journal of environmental research and public health, 14(10), 1265.

[2] Jusli, E., Nor, H. M., Jaya, R. P., & Zaiton, H. (2014). Chemical properties of waste tyre rubber granules. In Advanced Materials Research (Vol. 911, pp. 77-81). Trans Tech Publications Ltd.

[3] Baensch-Baltruschat, B., Kocher, B., Stock, F., & Reifferscheid, G. (2020). Tyre and road wear particles (TRWP)-A review of generation, properties, emissions, human health risk, ecotoxicity, and fate in the environment. Science of the Total Environment, 733, 137823.

[4] Klöckner, P., Reemtsma, T., Eisentraut, P., Braun, U., Ruhl, A. S., & Wagner, S. (2019). Tire and road wear particles in road environment – Quantification and assessment of particle dynamics by Zn determination after density separation. Chemosphere, 222, 714-721.

[5] Bijarimi, M., Francisco, V., Norazmi, M., Normaya, E., Arshad, S. E., & Alhadadi, W. (2021). Mechanical properties of poly (lactic acid) compounded with recycled tyre waste/graphene nanoplatelets nanocomposite. Materials Today: Proceedings, 42, 265-269.

[6] Collin, S., Bussière, P. O., Therias, S., Lambert, J. M., Perdereau, J., & Gardette, J. L. (2012). Physicochemical and mechanical impacts of photo-ageing on bisphenol a polycarbonate. Polymer degradation and stability, 97(11), 2284-2293.

[7] Unwin, J., Coldwell, M. R., Keen, C., & McAlinden, J. J. (2013). Airborne emissions of carcinogens and respiratory sensitizers during thermal processing of plastics. Annals of Occupational Hygiene, 57(3), 399-406.

[8] Canopoli, L., Coulon, F., & Wagland, S. T. (2020). Degradation of excavated polyethylene and polypropylene waste from landfill. Science of the Total Environment, 698, 134125.